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Assessment of land suitability for rice and maize: Case study in Lewa District, East Sumba, East Nusa Tenggara, Indonesia

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Abstract

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Lewa, one of the districts in East Sumba Regency, East Nusa Tenggara Province, is a dry land area with considerable land potential that has not been fully utilized. The potential of this land can be maximized, so an evaluation of land suitability is necessary to ensure the proper development of rice and maize. This study aims to determine the land characteristics and land suitability for rice and maize in Lewa, East Sumba. This research was conducted from January to June 2019. The analytical methods used were the matching method and overlay method, utilizing model-building extensions in *ArcView* 3.2 software. The results of land suitability analysis show that the land suitability class for rice is S1 (Highly Suitable) with an area of 12,212.03 ha (43.46%), S2 (Moderately Suitable) with an area of 15,753.53 ha (56.06%), and N (Not Suitable) with an area of 134.44 ha (0.48%). On the other hand, land suitability class for maize is S1 (Highly Suitable) with an area of 8,529.27 ha (30.35%), S2 (Moderately Suitable) with an area of 19,432.59 ha (69.16%), and N (Not Suitable) with an area of 138.12 ha (0.49%). The main limiting factors are oxygen availability (OA), such as drainage and soil depth, erosion hazard (EH), or slope, and land preparation (LP) or rock outcrops.

Keywords: land suitability; Lewa; rice; maize

Introduction

Food is the staple of human consumption. Along with the increasing number of people in Indonesia, the demand for food (rice and maize) is also increasing. It happens because most Indonesians use rice as their staple food, and maize is used as a substitute for rice in public consumption (Arifin et al., 2019). Therefore, as an effort to overcome and anticipate a food shortage, the government implements development and enhancement in the agricultural sector through a national program of food self-sufficiency. In planning, developing, and increasing food commodities, it is necessary to understand the components that affect plant growth, development, and production, especially the components of land characteristics such as climate, soil, and topography (Pramova et al., 2012).

The development and enhancement of rice and maize-based food commodities in an area can achieve success if the suitability of land characteristics with the growing conditions of these plants has been discovered. Land suitability evaluation can be done by comparing the requirements of land use with the quality (characteristics) of land (Hardjowigeno and Widiatmaka, 2007). Land suitability assessments may provide information about constraints and opportunities for land use. It serves as guidelines for the optimal use of land resources, making the information a requirement for

land use planning and development (Ayorinde et al., 2015). The use of land that is not suitable for its characteristics may inhibit the farming process and be one of the causes of crop failure (Prasetyo and Suriadikarta, 2006). There are many characteristics of the land, both in terms of physical and chemical properties, which can be a parameter in determining land suitability for a specific crop. Specifically, land suitability for a commodity is assessed based on the physical characteristics of the environment, including the level of soil fertility, climate, topography, hydrology, and drainage (Supriyadi et al., 2009).

Land suitability evaluation, as recommended by the Food and Agriculture Organization (FAO), is expected to provide information about the suitability class for a particular commodity in a specific area. The land suitability class consists of: 1) Highly Suitable (S1) which indicates that the land has no obvious limiting factor on crop production so that productivity can reach the range of 100-80% of its potential, 2) Moderately Suitable (S2) which indicates that land has a limiting factor that will reduce crop productivity so that it only reaches 80-60% of its potential, 3) Marginally Suitable (S3) which indicates that the land has a severe limiting factor so that crop productivity only ranges from 60-40% of its potential and 4) Not Suitable (N) which shows that there is a very severe limiting factor so that plant productivity only reaches a maximum of 40% of its potential (Banjarnahor and Simanjuntak, 2016). In addition, land assessment or land evaluation is expected to discover the best spot where plants can grow optimally, as well as the limiting factors of the land that will affect production decline. Thus, it is necessary to emphasize the limiting factors and improve land conditions to increase crop production (Rabia, 2012).

Lewa is one of the districts in East Sumba regency, East Nusa Tenggara province. It is an area where most of the farming business involves dryland farming, with potential land that can be developed through the rice and maize development program. Land potential needs to be better understood so that maximum production can be achieved through the development of rice and maize crops. Therefore, this study aims to determine the land characteristics and suitability for rice and maize cultivation in Lewa, East Sumba.

Method

Place and time of research

Soil sampling and primary data collection were conducted in Lewa District, East Sumba Regency, East Nusa Tenggara Province. Analysis of soil samples was done at the Soil Laboratory, Faculty of Agriculture and Business, Universitas Kristen Satya Wacana, from January to June, 2019.

Tools and materials

The tools used in this research to analyze the soil included GPS, plastic, label paper, stationery, and laboratory equipment, along with software such as ArcView 3.2 and QGIS 2.8. Furthermore, the materials used in this research are analyzed for texture, drainage/redox, pH, organic carbon (C), electrical conductivity (EC), and soil cation exchange capacity (CEC).

Analysis method

Land characteristics analysis (climate and soil)

To determine the condition of the environment and land in Lewa, it is necessary to collect data on soil characteristics. Data on soil characteristics were obtained by collecting climate data (rainfall and temperature) and taking and analyzing soil samples. The rainfall data used were obtained from the Meteorology, Climatology, and Geophysics Agency of East Nusa Tenggara and seven climatology stations in East Sumba Regency (Wanga, Tanarara, Ngongi, Malahar, Kananggar, Melolo, and Waingapu) and one climatology station in Central Sumba Regency (Lindiwacu) for the period from 2000 to 2015.

The data on soil characteristics were obtained by taking soil samples and analyzing them in the laboratory. The spot for soil sampling was determined using a simple random sampling method based on map overlays, which included land use maps, rainfall maps, slope maps, soil type maps, and administrative maps. Determination of the number of samples used in-depth observation based on land use maps by eliminating non-agricultural areas (especially forests and savannas). The results of the determination were obtained from 37 sample spots scattered throughout the Lewa district area. Soil characteristics, including soil type, surface rock, and coarse material, were obtained during field surveys. Meanwhile, data on land characteristics, including texture, drainage/redox, pH, organic carbon, electrical conductivity (EC), and cation exchange capacity (CEC), were obtained from the analysis results of soil samples at the Soil Laboratory in Universitas Kristen Satya Wacana Salatiga.

Land suitability analysis

The land suitability assessment was carried out using two methods: 1) Matching method, which compares the land characteristics as parameters measured in the field and laboratory with the land suitability criteria compiled based on plant growth requirements according to information from Djaenudin et al., 2003); 2) Overlay method is carried out by giving balanced scores and weights to climate and land characteristics through a built-in extension model in Arcview 3.2 software so that the land suitability class can be determined. A balance was struck between climate and soil characteristics, assuming that these characteristics have a similar effect on land suitability

for crops. Climate characteristics were assigned a score of 50, divided into rainfall and temperature categories. Meanwhile, soil characteristics were assigned a score of 50, encompassing drainage, texture, coarse material, effective depth, cation exchange capacity (CEC), pH, organic carbon, redox, electrical conductivity (EC), slope, and rock outcrops. Weighting is carried out based on the suitability of rice and maize land, with values of 4 for suitability S1, 3 for suitability S2, 2 for suitability S3, and 1 for suitability N.

Results and Discussion

Land characteristics in Lewa

Lewa is one of the districts in East Sumba regency, East Nusa Tenggara province. The Haharu district administratively borders it to the north, the Lewa Tidahu district to the south, Nggaha Ori Angu to the east, and the Central Sumba Regency to the west. It has an area of approximately 28,100 ha, consisting of one sub-district and seven villages: Lewa Paku Vil-

Table 1. Land characteristics in the Lowa District

Sample	Drainage/ Redox (mV)	CEC (me /100g)	pH	C-Organic (%)	Texture	EC (dS/m)	Surface Stoniness (%)	Coarse Material (%)	Soil Depth (cm)	Slope (%)
L1	87.70	22.13	5.00	2.66	Clay	0.6	<5	<3	54.9-74.8	<8
L2	68.00	20.08	5.38	5.84	Clay	2.5	<5	<3	35-54.9	<8
L3	68.40	15.45	6.03	2.95	Clay	0.5	<5	<3	35-54.9	<8
L4	(14.10)	17.66	6.89	3.67	clay loam	1.7	<5	3-15	35-54.9	25-40
L5	55.40	10.20	5.68	5.07	Clay	0.7	<5	<3	>74.8	<8
L6	(14.00)	22.93	6.20	4.96	Clay	2.5	G<5	<3	54.9-74.8	<8
L7	87.10	13.80	5.47	5.55	Clay	2	<5	<3	54.9-74.8	<8
L8	79.30	27.54	5.48	5.23	Clay	2.5	>40	>25	<35	15-25
L9	108.30	17.77	5.31	4.34	Clay	1.2	<5	<3	54.9-74.8	<8
L10	54.30	25.00	5.98	6.15	Clay	1.1	<5	<3	54.9-74.8	25-40
L11	44.90	26.40	6.08	5.47	Clay	2.7	<5	<3	>74.8	15-25
L12	34.10	14.28	6.65	5.55	Clay	1.4	<5	<3	54.9-74.8	>40
L13	57.80	36.67	5.73	6.97	Clay	3.6	<5	<3	35-54.9	25-40
L14	15.10	35.90	6.80	5.56	Clay	1.5	<5	15-25	<35	15-25
L15	54.00	30.03	6.26	5.14	Clay	1.7	15-40	<3	54.9-74.8	8-15
L16	72.30	23.93	5.86	3.85	Clay	1.8	<5	<3	54.9-74.8	<8
L17	74.90	19.46	5.99	3.81	Clay	0.7	<5	<3	35-54.9	15-25
L18	44.80	37.58	6.03	4.15	Clay	2.8	5-15	<3	54.9-74.8	>40
L19	62.20	23.30	5.89	5.43	Clay	2.2	<5	<3	54.9-74.8	<8
L20	45.30	13.02	6.17	5.26	Clay	1.4	<5	<3	>74.8	<8
L21	22.20	14.44	6.32	5.86	Clay	2.8	<5	<3	54.9-74.8	<8
L22	56.60	27.41	5.86	3.86	Clay	2.1	<5	<3	54.9-74.8	15-25
L23	40.30	11.58	6.28	5.29	Clay	4.7	<5	<3	<35	25-40
L24	0.80	34.11	6.59	6.82	Clay	4.8	<5	3-15	54.9-74.8	25-40
L25	39.00	27.93	6.22	7.00	Clay	4	<5	<3	54.9-74.8	<8
L26	67.10	13.21	6.12	5.99	Clay	3.8	<5	<3	35-54.9	<8
L27	47.70	17.37	6.09	6.48	sandy-silt loam	2.5	<5	<3	54.9-74.8	25-40
L28	30.00	46.91	6.39	5.08	Clay	4.2	<5	<3	35-54.9	15-25
L29	93.80	7.30	5.16	3.17	clay loam	0.3	5-15	15-25	35-54.9	15-25
L30	88.40	28.69	5.25	5.88	Clay	4.1	<5	<3	35-54.9	15-15
L31	69.00	13.99	6.59	6.38	clay loam	0.5	5-15	<3	<35	8-15
L32	76.80	6.78	6.59	3.24	clay loam	0.1	5-15	3-15	35-54.9	25-40
L33	23.70	7.51	6.08	4.69	Clay	2.2	<5	<3	>74.8	<8
L34	39.60	27.61	5.94	5.39	Clay	3.8	<5	<3	54.9-74.8	<8
L35	109.70	8.85	5.06	3.98	Clay	0.7	<5	<3	35-54.9	<8
L36	102.50	17.77	5.27	4.37	Clay	0.8	<5	<3	54.9-74.8	<8

Source: Data processing results (2019)

lage, Tanarara Village, Kambu Hampang Village, Kondamara Village, Matawai Pawali Village, Rakawatu Village, and Bidihunga Village. Lewa is situated between 500-669 m above sea level (Central Statistics Agency (CSA), 2015).

Based on data analysis from eight climatology stations, the average annual rainfall in Lewa is obtained to be between 1,360 and 1,949 mm. The air temperature ranges from 22.1°C to 25.7°C, according to calculations using the Braak equation (1928, as cited in Djaenudin et al., 2003). The characteristics of the land in Lewa are various (Table 1). The texture of the soil consists of clay, clay loam, and sandy-silt loam, with a neutral acidity that ranges from 5 to 7. The drainage is determined based on measurements of redox potential under reduced conditions or when the soil is constantly inundated with water. The organic carbon content and the value of cation exchange capacity (CEC) in the soil vary from low to very high. At the same time, the coarse materials and rock outcrops in the observation area are classified as ranging from very few to many. Soil salinity is classified as non-salinity to low conditions based on measurements of soil electrical conductivity (EC). Moreover, the adequate depth of soil in the observation area varies from shallow to deep classes, while the slopes in Lewa vary from flat to steep (<8 to> 40%).

Land suitability for rice

Based on the results of the land suitability class analysis with overlay method using the extension model builder in Arcview software by giving a balanced score and weight on the characteristics of the land, where the climate characteristics were given a score of 50 (divided by weight 25 between temperature and rainfall) and soil characteristics were weighted 50 (divided by weight 5 of texture, pH, CEC, organic-C, redox, EC, solum depth, rock outcrops, coarse material and slope), the three classes of land suitability for rice in Lewa (figure 2) are obtained, which are: S1 (Highly Suitable) 12,212.03 ha (43.46%), S2 (Moderately Suitable) 15,753.53 ha (56.06%) and N (Not Suitable) 134.44 ha (0.48%). From the analysis results, it is evident that in Lewa, most of its territory remains dominated by the S2 land suitability class (Moderately Suitable) for rice cultivation and development. However, there needs to be an enhancement on the existing limiting factors, so that their suitability becomes S1 (Highly Suitable). The results of matching land characteristics parameters with land suitability criteria, as per Djaenudin et al. (2003), identified the main limiting factors, namely oxygen availability (OA), such as drainage and depth, erosion hazard (EH) or slope, and land preparation (LP) or rock outcrops. The drainage limiting factors can determine the type of plant that can grow, as they are related to the availability of oxygen in the soil. Hardjowigeno (2007) states that rice plants can live in poorly drained or inundated soils. In areas with obstructed drainage, it is not influential because rice crops have internal root O2 exchange systems, which, even when inundated, are still able to respire (Utomo et al., 2016). The limiting factor of the depth is classified as permanent because it cannot be repaired. If the reparation is highly required, it will only be carried out by adding organic material as a planting medium. The limiting factor of rock outcrops is their permanence and difficulty in repair. The limiting factor of slope is related to the occurrence of

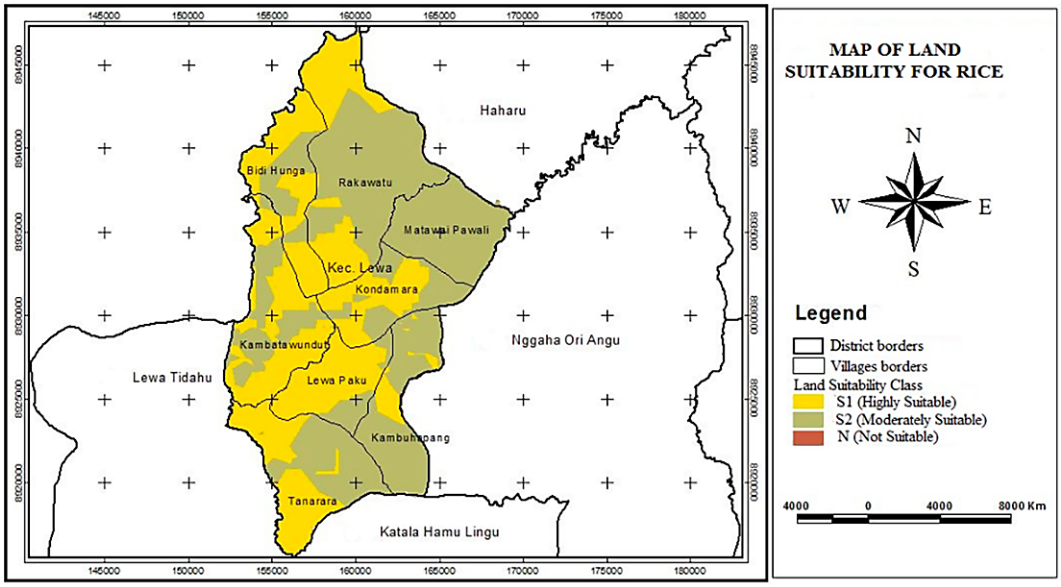

Fig. 1. Map of land suitability for rice
Source: Data processing results (2019)

surface erosion, which can reduce soil fertility levels. Slope factors can be updated in several ways, one of which is by making a terrace in a sloping area to reduce erosion (Panagos et al., 2015).

Land suitability for maize

Based on the results of the land suitability class analysis with overlay method using the extension model builder in Arcview software by giving a balanced score and weight on the characteristics of the land, where the climate characteristics were given a score of 50 (divided by weight 25 between temperature and rainfall) and soil characteristics were weighted 50 (divided by weight 5 of texture, pH, CEC, organic-C, redox, EC, solum depth, rock outcrops, coarse material and slope), the three classes of land suitability for rice in Lewa (Figure 2) are obtained, which are: S1 (Highly Suitable) 8,529.27 ha (30.35%), S2 (Moderately Suitable) 19,432.59 ha (69.16%), and N (Not Suitable) 138.12 ha (0.49%). The land suitability class S2 is the dominant class, covering almost the entire area of the district. Nevertheless, it requires management of the existing limiting factors to improve the suitability class for maize crops to land suitability class S1. The results of matching the parameters of land characteristics with land suitability criteria, based on Djaenudin et al. (2003), identified the main limiting factors, namely oxygen availability (OA), such as drainage and soil depth; erosion hazard (EH), or slope; land preparation (LP); and rock outcrops. The land suitability class of the oxygen availability limiting factor for drainage in maize crops can be improved or enhanced by increasing irrigation and constructing drainage channels (Wirosoedarmo et al., 2011). A well-drained drainage is required for the crops that need good aeration, such as maize. Then, well-soil aeration causes oxygen availability in the soil to be sufficient. Therefore, crop roots can absorb nutrients and develop well (Wirosoedarmo et al., 2011). Improvements to drainage are necessary because maize crops will not grow well if the soil remains constantly inundated (Breidenbach et al., 2016). The limiting factor of the depth is classified as permanent because it cannot be repaired. If the reparation is highly required, it will only be carried out by adding organic material as a planting medium. The limiting factor of rock outcrops is their permanence and difficulty in repair. The limiting factor of slope is related to the occurrence of surface erosion, which can reduce soil fertility levels. Erosion hazard limiting factors for maize can be managed by cutting slopes with contour terrace and bench terrace systems to reduce soil erosion (Wirosoedarmo et al., 2011).

Conclusion

The results of the survey and laboratory analysis show that the characteristics of the land in Lewa District are varied. The soil textures consist of clay, clay loam, and sandy-silt loam, with neutral acidity that ranges from 5 to 7. The contents of organic C and the values of CEC in soil vary from low to high. Then, the coarse materials and rock outcrops in the observation area are classified as being very few to many. The adequate soil depth in the observation areas varies from shallow to deep classes. The results of the land suitability analysis using the overlay method of land characteristics show that the land suitability classes for rice are S1 (Highly Suitable), 12,212.03 ha

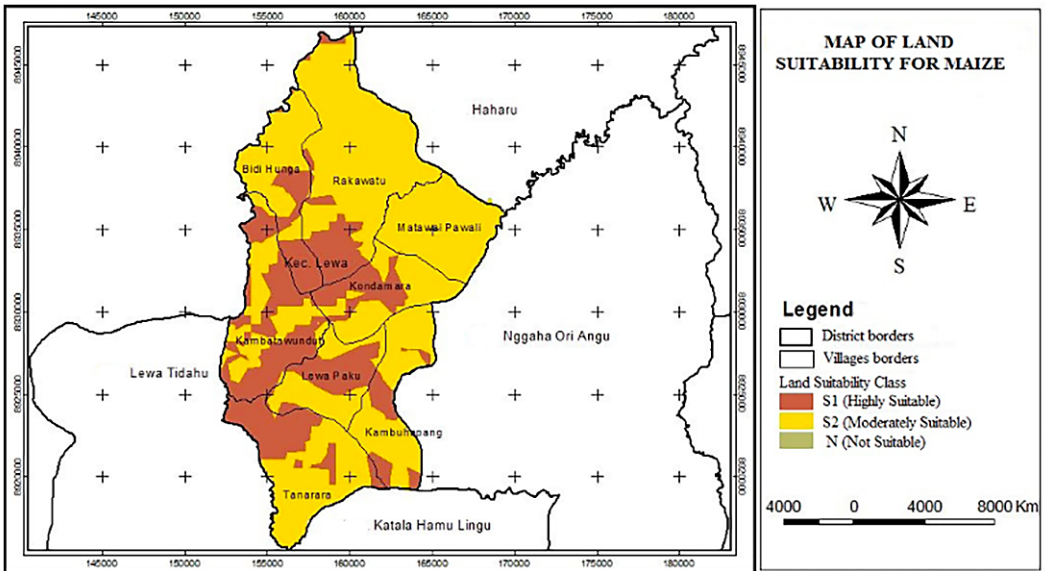

Fig. 2. Map of land suitability for maize
Source: Data processing results (2019)

(43.46%), S2 (Moderately Suitable), 15,753.53 ha (56.06%), and N (Not Suitable), 134.44 ha (0.48%). Meanwhile, the suitability classes of the maize fields are S1 (Highly Suitable), 8,529.27 ha (30.35%), S2 (Moderately Suitable), 19,432.59 ha (69.16%), and N (Not suitable), 138.12 ha (0.49%). The results of matching the land characteristics with the growing conditions of rice and maize reveal the main limiting factors, which are the oxygen availability (OA), such as drainage and soil depth, erosion hazard (EH) or slope, and land preparation (LP) or rock outcrops.

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